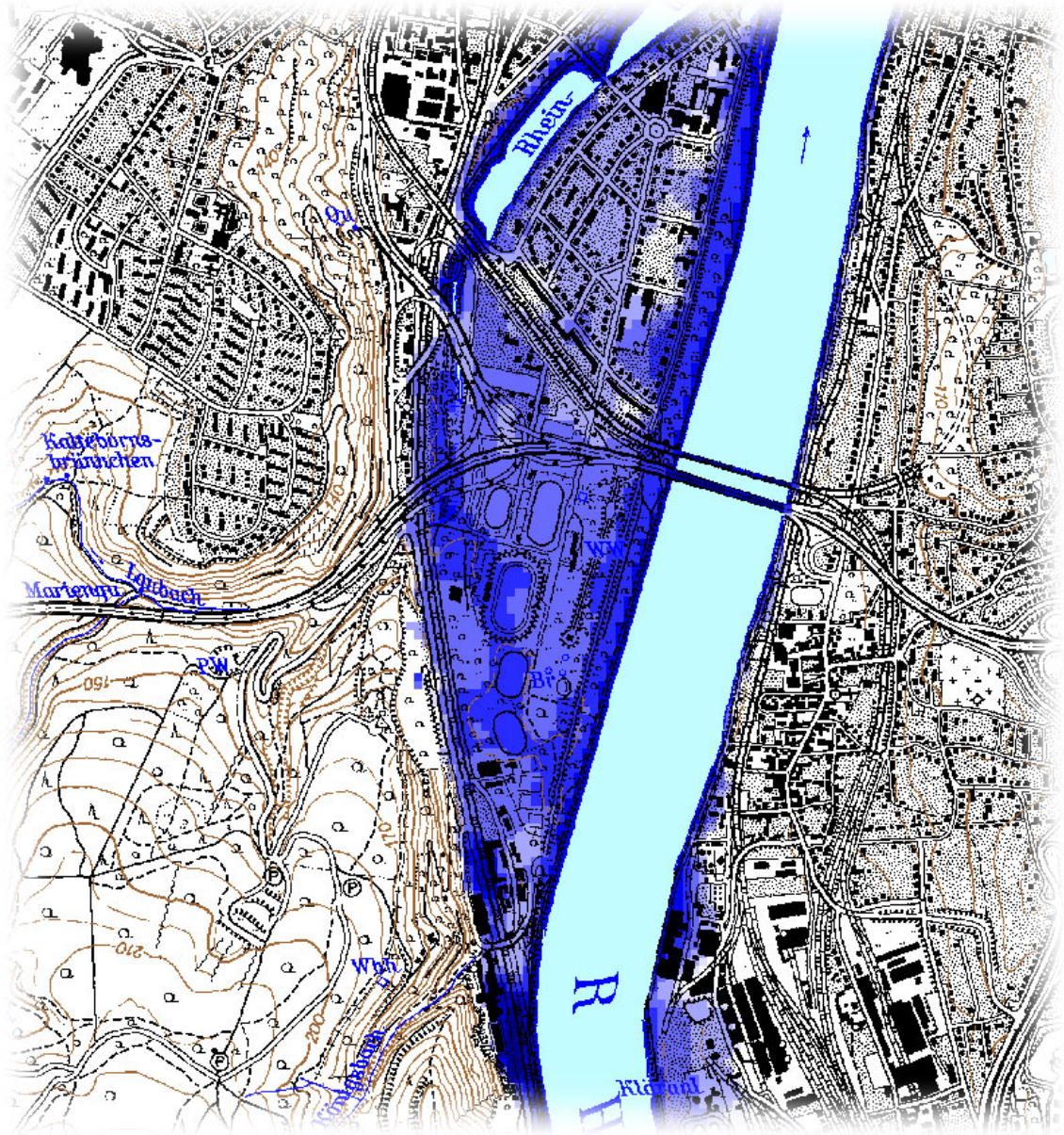


FloodArea –
ArcGIS extension for
calculating flooded areas

*User
manual*



Version 9.0 – July 2005

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Preface

Floods are natural processes. Urbanization and increasing population density as well as a concentration of economic values in flood prone areas have increased the risk in many regions. Natural flood plains all over the world are being settled or and used for industrial purposes. Perception of the flood hazard and the associated risks in many cases is low, if not inexistent, particularly in such areas considered to be safe, e.g. behind dams or levees.

New planning approaches, though, try to counteract these developments and create suitable flood protection concepts. In this process, the delineation of flood prone areas is a very important first step. Additional information in this delineation process is achieved by the calculation of water levels at any given point at different times during a flood event. Such information delivers very important basic data for the determination of the risk potential. In addition the possibility to simulate the temporal dynamics of the flood event produces important information for disaster management plans.

FloodArea enables the user to do both types of analysis. This manual explains in detail the application of the software. Relevant examples are being given. The particularities of the computational algorithms are also explained in detail.

FloodArea is an ArcGIS extension, which is completely integrated in the graphical user interface of ArcGIS desktop, utilizing Spatial Analyst functionality. No details of ArcGIS or Spatial Analyst are explained here. The user is assumed to be familiar with the use of ArcGIS in general and ArcMap and Spatial Analyst in particular. Reference is given in the respective manuals or via online help.

FloodArea is a joint product of geomer GmbH, Heidelberg, Germany, and Ingenieurgesellschaft Ruiz Rodriguez + Zeisler, Wiesbaden, Germany.

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What FloodArea Can Do For You

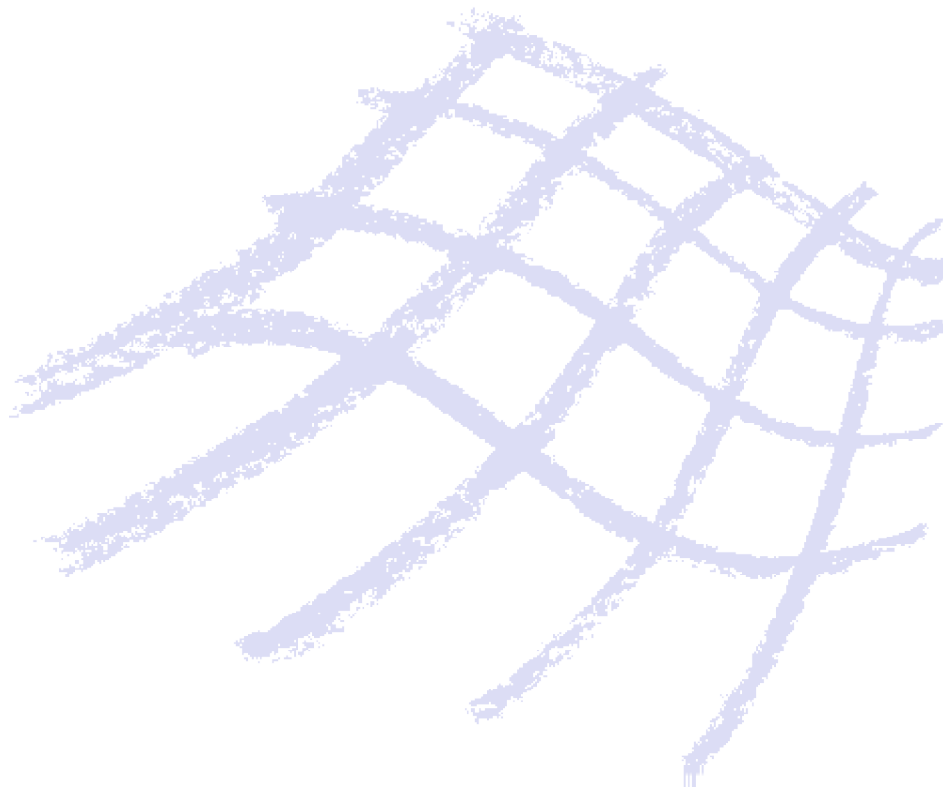
The main purpose of **FloodArea** is the delineation of flooded (inundated) areas. Calculations are based upon

- a drainage network grid with water levels assigned to it. Though the water levels can vary spatially (e.g. along a river stretch) they remain constant during the simulation process. The water levels can be changed, however, by modifying them between single model runs, or by
- one or more hydrographs at user definable coordinates, or by
- a rainstorm simulation over a wider area, specified by a weighted Grid.

Model results are stored as Grids at user defined intervals, providing for the possibility to reproduce the temporal aspect of the flooding process. The values of the resulting Grids can be stored as absolute height levels or as values relative to the surface. If needed, the flow direction vectors can be output for each individual grid.

Additional parameters can be specified for a simulation run. Flow barriers (e.g. road embankments), which are not represented by the elevation model, can be specified. Locations of dam failures can also be specified determining at which points flow barriers fail, making dike break scenarios possible.

To adapt the flow velocities to real world conditions, the user can specify roughness values.



Installing and Loading FloodArea

System Requirements

Minimum requirements are ArcGIS ArcView 9 or higher and the Spatial Analyst extension, a Pentium-processor with Windows NT 4.0, 2000 or XP and 128 MB RAM. Recommended are 256 MB RAM and 100 MB free disk space.

The maximum Grid size for **FloodArea** depends on free memory. Increasing the virtual memory is not an option because disk swapping will reduce processing speed tremendously.

Disk space requirements depend directly on the number of intermediate simulation Grids.

Installation

The Installation of **FloodArea** will be accomplished by using the install-setup program. If the autorun option is switched off, you can start the installation by running floodarea_setup.exe.

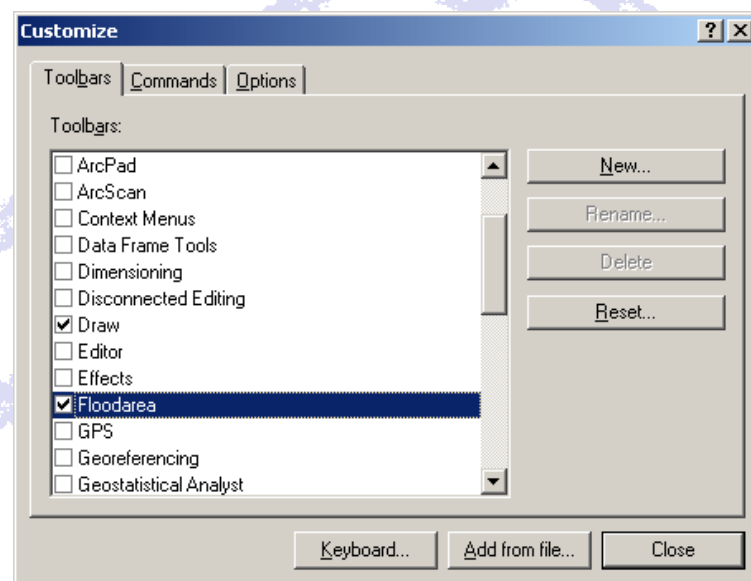
For de-installing **FloodArea** please use the function provided by the operating system.

Demo data and ArcMap project

The installation procedure will copy an ArcMap document (mxd-file) with associated data and also this manual to the selected installation directory path. Please read additional explanations in chapter Demo project on page 35.

Activating the FloodArea toolbar

After installing FloodArea a new toolbar can be activated in the cutomize dialog by clicking *Tools, Customize* and checking the FloodArea option.



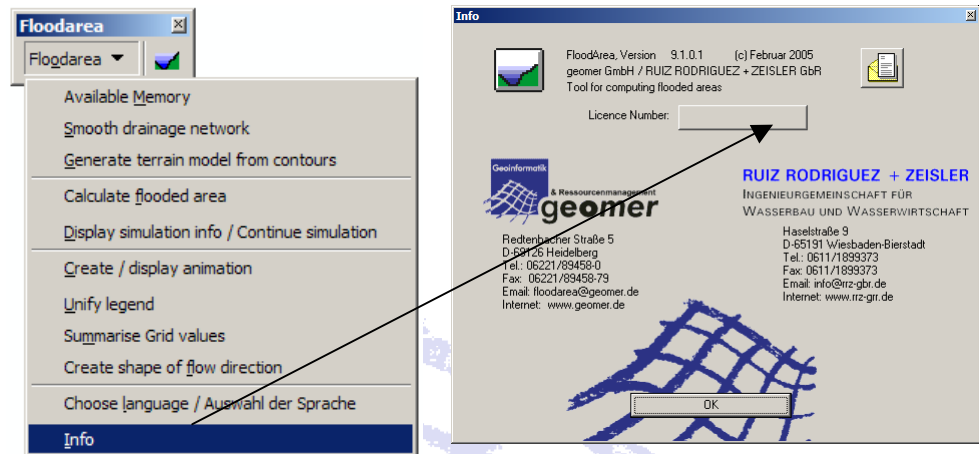
Registering your license

To be able to make full use of **FloodArea** with your own data you need to register your license. You will be asked to do so after any new start of ArcMap, until a valid license code is entered.



If a valid license code is not entered **FloodArea** can still be used with it's full functionality. However, it will not be possible to work with data other than the data provided with the demo project. After entering a valid license code, the dialog won't show again.

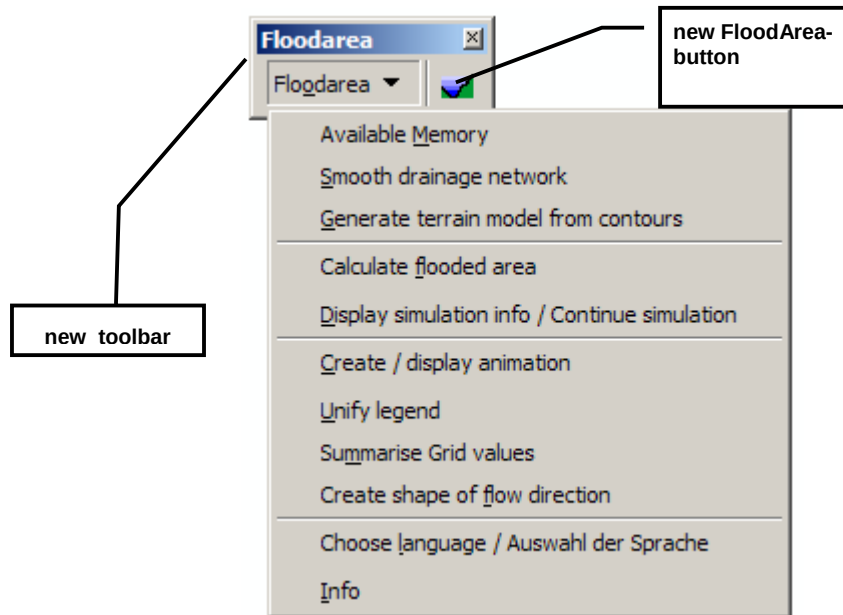
The dialog for entering a valid license code can also be activated by using the menu *FloodArea, Info*.



Using FloodArea

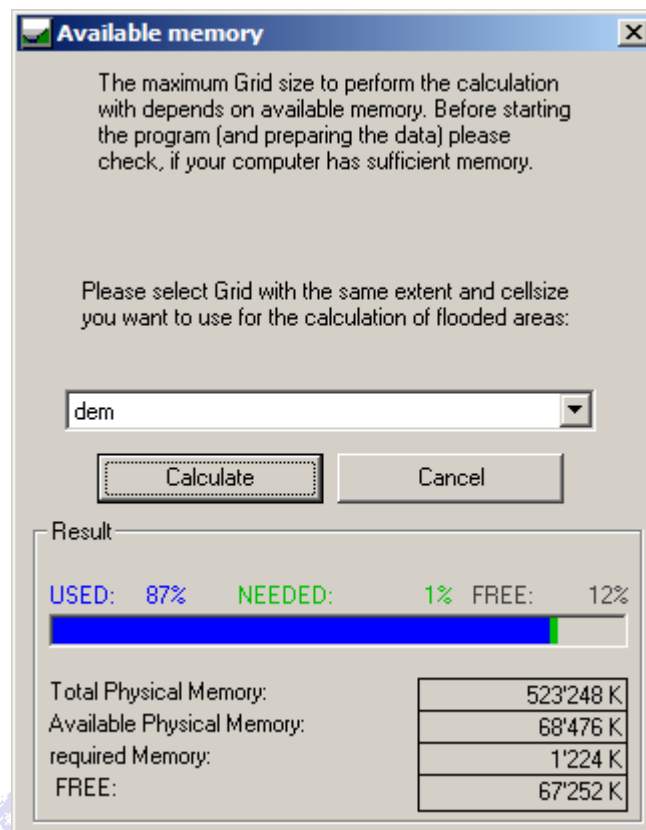
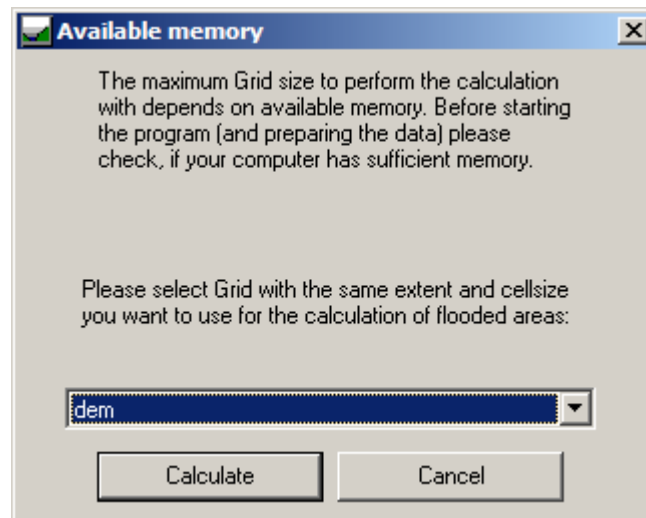
The FloodArea Main Menu

After loading the **FloodArea**, its toolbar can be used just like any other toolbar. The available sub-menus are shown in the figure below. The most important entry *Calculate flooded area* is accessible also by the **FloodArea** button .



Available memory

Use this option to check if enough memory is available for the simulation. Please note that the given value is an estimate only, since all other running programs and the operating system itself use the available memory in concurrent operations. The given percentage is based on the physical memory only. Try to avoid using virtual memory. In this dialog you can select from a list of raster data layers from the active data frame or load one from disk. In the latter, the selected layer will be added to the data frame.



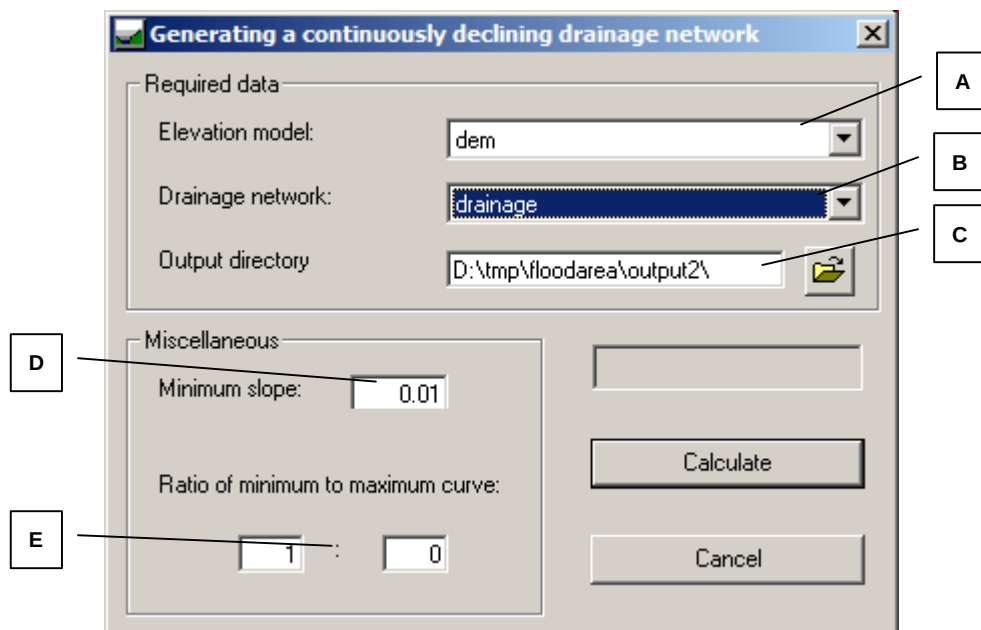
After confirming by clicking the **Calculate** button, a message box appears showing memory requirements and the information whether it is sufficient to run your model. Choose **Cancel** to abort this estimation.

Avoid simulation runs requiring memory above the available real memory. Using virtual memory may increase processing time tremendously.

Smooth drainage network

Use this option to smooth drainage networks generated from digital elevation models, or rasterized drainage networks derived from vector lines. In the context of **FloodArea**, smoothing means that intersecting the drainage network with the elevation model generates a continuously inclined water level in flow direction. This is useful because rasterized networks often do not follow drainage lines represented in digital elevation models, which contain sinks and gaps.

The dialog for controlling this function is shown below and contains the described elements.



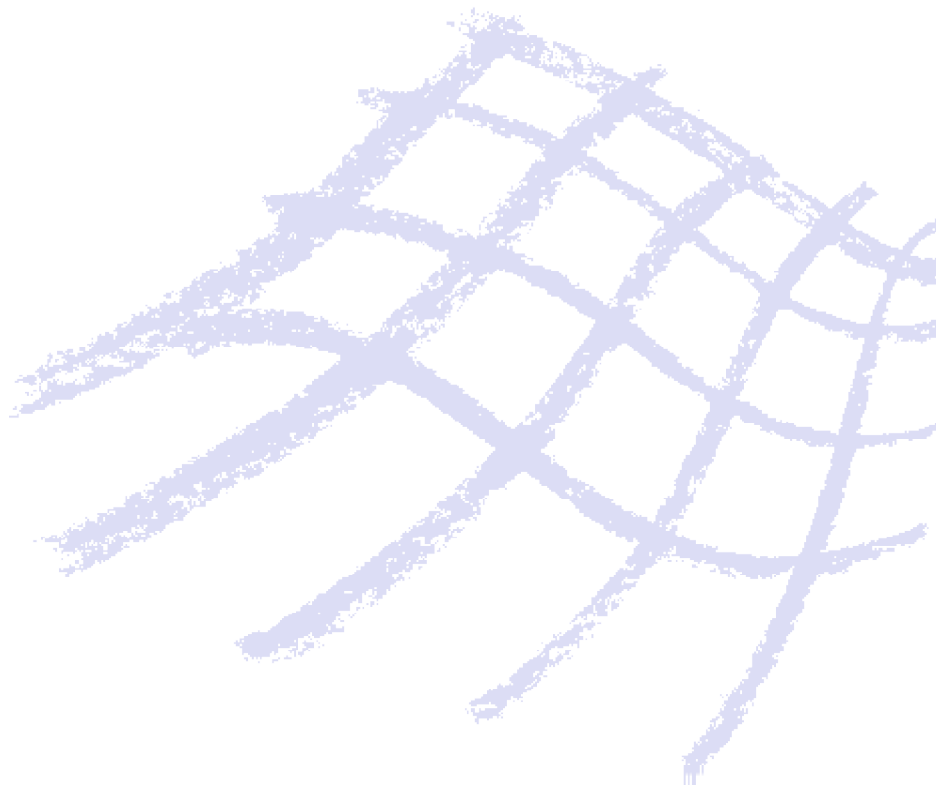
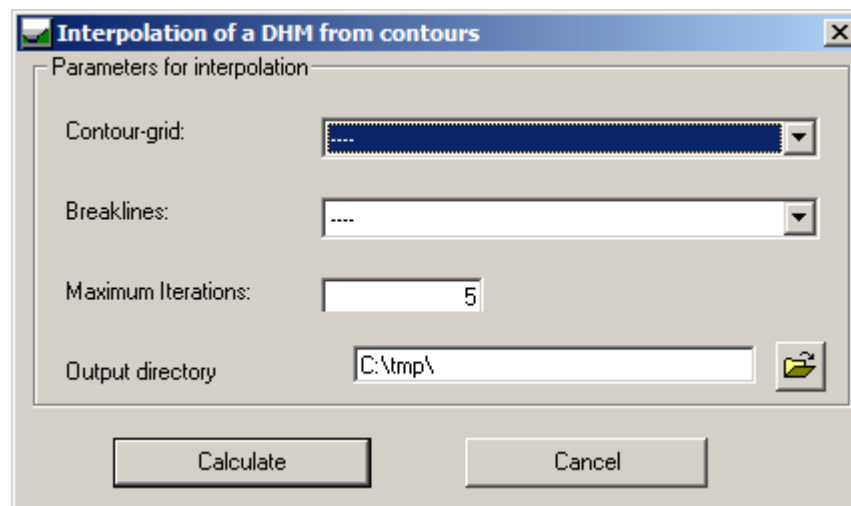
In **listbox A** specify the *Elevation model* from which the drainage network was generated or to which the resulting drainage will be intersected. As *Drainage network* (**listbox B**) a drainage network with elevation data must be chosen. *Minimum slope* (**textbox D**) specifies the minimum gradient in units of the elevations of the drainage network itself. The smallest acceptable value is 0.001.

The *Ratio of minimum/maximum curve* (**textbox E**) defines how the two created curves are being intersected. The value must be chosen according to the errors assumed for the elevation grid. If, for example, the elevation model contains erroneous flow barriers near drainage lines produced by vegetation or bridges, it would make sense to “cut” only those elevations and use the minimum curve. If elevation errors are distributed irregularly, use a 1:1 ratio to preserve the characteristic features of the drainage vector profile. The resulting Grid will always be named “Smoothing”. It will be saved in the selected directory (**textbox C**) as a rasterized drainage network with elevation values.

Click on *Calculate* to start.

Generate terrain model from contours

Use this function to create a digital elevation raster from rasterized contour lines. The approach on FloodArea differs from the standard interpolation routines provided by Spatial Analyst. Values for raster cells are interpolated between lines rather than along lines. This avoids negative effects like “stairs” in the resulting DEM.



Calculate flooded areas

This is the core option of **FloodArea**. Use this menu for hydrodynamic modeling of flood areas for given water levels.

Prerequisites

For calculating inundation areas using **FloodArea** a minimum of two input raster layers are needed:

- a digital elevation model
- a rasterized drainage network, or points with attached hydrographs, or a rainstorm distribution raster with attached hydrograph

It is recommended to define the map units in the data frame properties. If not set, meters will be assumed. Please be aware, that wrong units will produce wrong flow volumes and velocities, and thus will lead to unusable results. However, map units can be set also later on in the main dialog of FloodArea. (Calculation of flooded areas)

Data Frame Properties

Annotation Groups | Extent Rectangles | Frame | Size and Position

General | **Data Frame** | Coordinate System | Illumination | Grids | Map Cache

Name: FloodArea

Description:

Units

Map: Meters

Display: Unknown Units

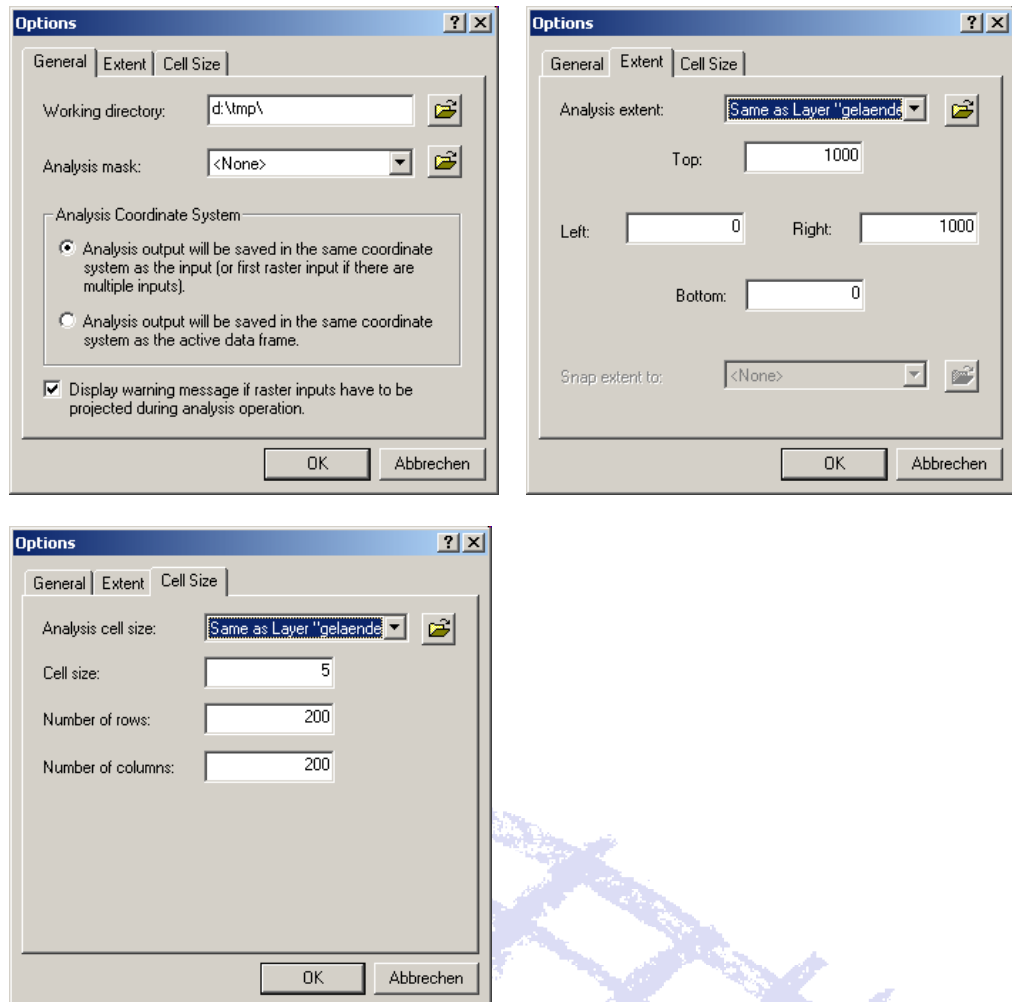
Reference Scale: 1 : 0

Rotation: 0

Label Engine: ESRI Standard Label Engine

OK Abbrechen Übernehmen

Before starting the calculation the analysis environment of Spatial Analyst should be defined. It is recommended to use the extent and cell size properties of the elevation model upon which the model run is based. To accomplish this, call the options dialog of Spatial Analyst as shown below.

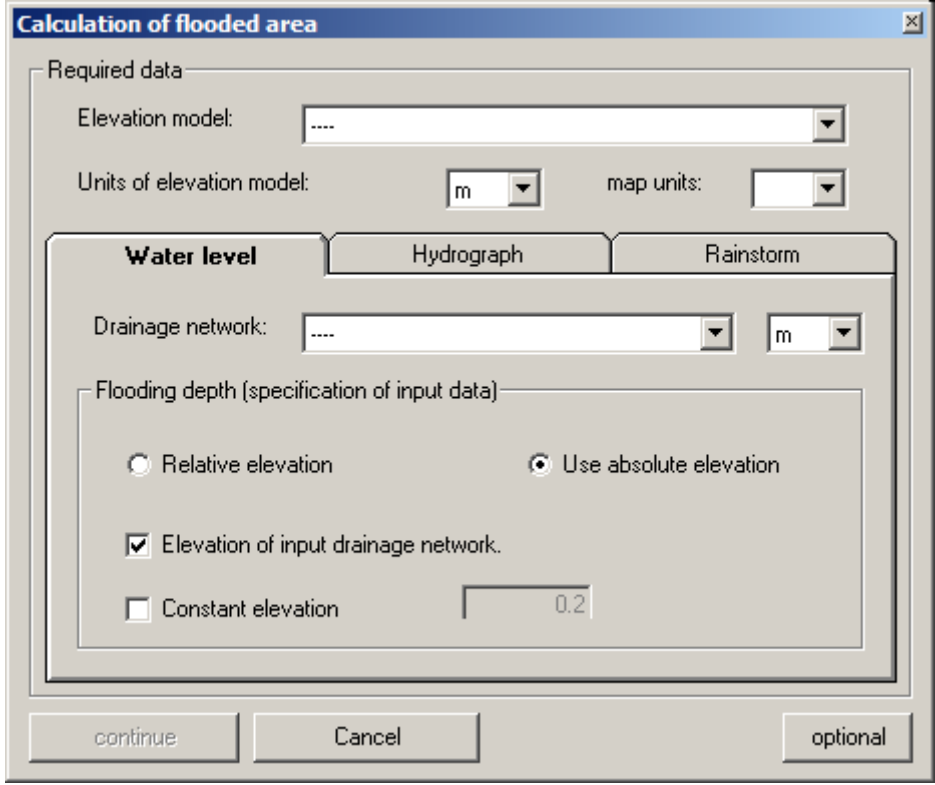


The model run will be done for the extent defined here. If not set or not properly set, an empty GRID could be the result of a simulation run.

Running a simulation

This option is available also through the **FloodArea** button .

Start the simulation definition by activating the main dialog.



The user has the choice between three variations of simulation. They differ in the way the water is input to the simulation model.

Using the option **Water level (elevation of drainage network)** assumes that flooding is initialized by the entire drainage network, meaning from all grid cells other than NoData). Water levels can vary spatially but remain temporally constant during the simulation process.

Using the option **Hydrograph (input by single cell)** water enters the model at defined locations. This option makes a temporal variation (hydrograph) of water levels possible (see below how to specify hydrograph data).

The third option **Rainstorm** (areal input) is very similar to the second one. The difference between the second and the third option is that the water levels of this model are defined by a Grid.

Press **Cancel** to abort the model run.

Water level (elevation of drainage network)

Using this model option requires at least the specification of the following layers:

- a digital elevation model, which represents the surface upon which the flow process takes place, including its elevation units
- a rasterized drainage network containing elevation values of water levels (above sea level or above surface)

Both raster layers can be selected from a list of available layers or loaded from disk.

Calculation of flooded area

Required data

Elevation model: dem

Units of elevation model: m map units:

Water level Hydrograph Rainstorm

Drainage network: drainage m

Flooding depth (specification of input data)

☒ Relative elevation ☐ Use absolute elevation

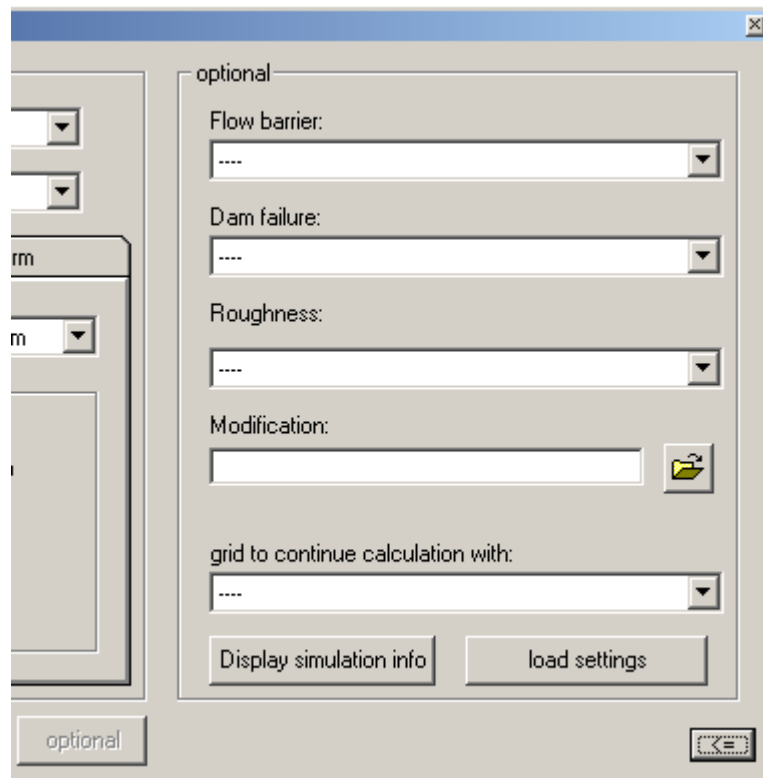
☒ Elevation of input drainage network.

☒ Constant elevation 0.2

continue Cancel optional

In addition two fields for specifying elevation units and map units are available. Elevation units or the elevation models must be given. Elevation units for the drainage network are optional, they will be ignored in the case where a calculation is based on a constant flood level (e.g. 1.5 meter above surface).

Additional optional Grids can be taken into account by clicking on *optional*



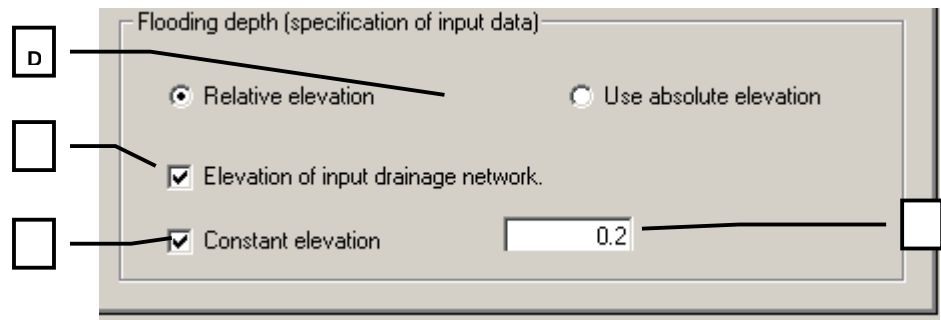
Modification: With this option it is possible to rise or lower the complete water level during the simulation process. The file to be selected here has to have the same format than the hydrographs used within the other options (see page 15). The values will always be interpreted as the difference to the original water level in centimeters. The values between the data in the input file will be interpreted linearly. With this function you can simulate for example the passing through of a flood wave within a bigger river and the effects on the connected retention areas.

Flow barriers: All grid cells other than 0 (zero) or NODATA are considered to be flow barriers. The model algorithm uses diagonal transfer between grid cells. Thus, in order to function as a true flow barrier, grid cells must be edge-connected. Grids generated by ArcViews' rasterizing of line shape files meet this requirement. No heights of dams can be specified here. If these are available and to be used in the simulation, they must be part of the elevation model. Use the standard SpatialAnalyst functions to modify your elevation model accordingly.

Dam failure: All Grid cells other than 0 (zero) or NODATA are considered to be superior to flow barriers. Superior means that at any given location (i.e. grid cell) where both flow barrier and dam failure are set, the dam failure Grid takes priority. You can use this option for the simulation of dam failures.

Roughness: A Grid representing roughness values according to Manning. Values have to be given as $1/n$, n in units of $m^{1/3}s$.

To specify water levels several options are available.



Water level (flood level elevations) is represented by the values of the input drainage network Grid (**box A** is checked).

Water level (flood level elevations) is represented by the values of the input drainage network Grid, but in addition a constant value (specified in **field c**) is added. **Box A and B** must be checked for this method. Elevation units are the same as for the elevation model.

All drainage network grid cells have a constant value. The values of the cells are ignored. In order to apply this method **checkbox A** must be **deactivated** and **checkbox B** must be activated.

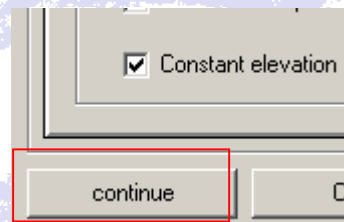
At least one of the checkboxes A and B must be activated!

For all options the water level elevations can represent relative values above the ground, or absolute values, e.g. above sea level. Use **option D** to make your choice.

Before actually starting the model run, the plausibility of the user input is being tested. In case of problems, the user is given some information about possible erroneous input.

For example, **FloodArea** checks for missing or wrong specifications in the various input fields. It also checks for alignment problems between input Grids.

Only after successfully testing the plausibility will the *continue* button be activated and clickable.



After clicking the continue button, the dialog box “Additional Settings” will open, which will be explained on page 18

Hydrograph (input by single locations)

Using this option implies that input for a drainage network with associated water level data is not required and can be ignored. Water is fed into the model through a hydrograph data file at one or more locations.. The name of this data file can be entered directly or selected from a file dialog.

Calculation of flooded area

Required data

Elevation model:

Units of elevation model: map units:

Hydrograph

Hydrograph:

Nr.	X-value	Y-value
1.	792	378

add new
edit
delete

☒ show markers

continue Cancel optional

The hydrograph data file is simply an ASCII text file, that can be created with any text editor. It must have the extension ".txt" and must be organized according to the figure below.

1. Column:	0.00	20.1	2. Column: Discharge in m³/sec
	0.05	22.8	
	0.17	25.2	
	0.33	24.3	Decimal separator: dot
	0.50	25.3	
	0.67	26.2	
	0.83	23.9	
	1.00	24.8	

To separate the columns the following tags are admitted: blank, tab, comma, semicolon or colon

The file has at least two columns, one holding the time (in decimal hours), the second and all others holding the discharge (in m³/s). The decimal sign must be a dot, columns may be delimited by either a space, a tab stop, a comma, a semi-colon or a colon. No empty lines or inline comments are allowed. Comments, though, may be added as separate columns. But they should not contain any numbers.

Negative discharge values are valid, although their usage is not recommended. If values are negative, the corresponding amount of water at that point will be interpreted as being taken out from the model. The algorithm does not comply with situations, where the negative value is higher than the amount of water currently available at that particular raster cell. Such assumptions may produce errors in the overall budget.

Time steps need not be regular. The program interpolates linearly between the specified time steps. If simulation time (see **Additional settings**) is reached before all hydrograph data are processed, the model stops.

The hydrographs input locations are specified by the input coordinates. The hydrographs are assigned to the input coordinates of the digitizing tool in the same order as the columns of the input file. Note that the numbering of the coordinates starts with 0. If either the column or the input coordinate is missing, the corresponding input will be neglected.

The input coordinate at which water is “fed” to the model are specified either by entering the easting and northing values directly in the respective fields or by using the digitizing tool. This tool is activated as soon as the user is typing in one of the fields. The cursor symbol will change to a cross and the message “Digitizing active” will appear in red color.

A maximum of 50 coordinates can be digitized using the option *add new*. Each coordinate must have one column in the hydrograph file. The correct center of the raster cell will be in proper alignment with the elevation model. The digitizing mode will be disabled as soon as a different tool will be activated by the user.

The amount of water leaving the model area at its edges is summed up for each time step of the hydrograph input file and written to an external file with the same name, but with a different file name extension (.out). Volumes are saved in units of m³. The third column of this file indicates the amount of water which left the model at the output location, also in units of m³. Please be aware that already existing files with the same filename will be overwritten.

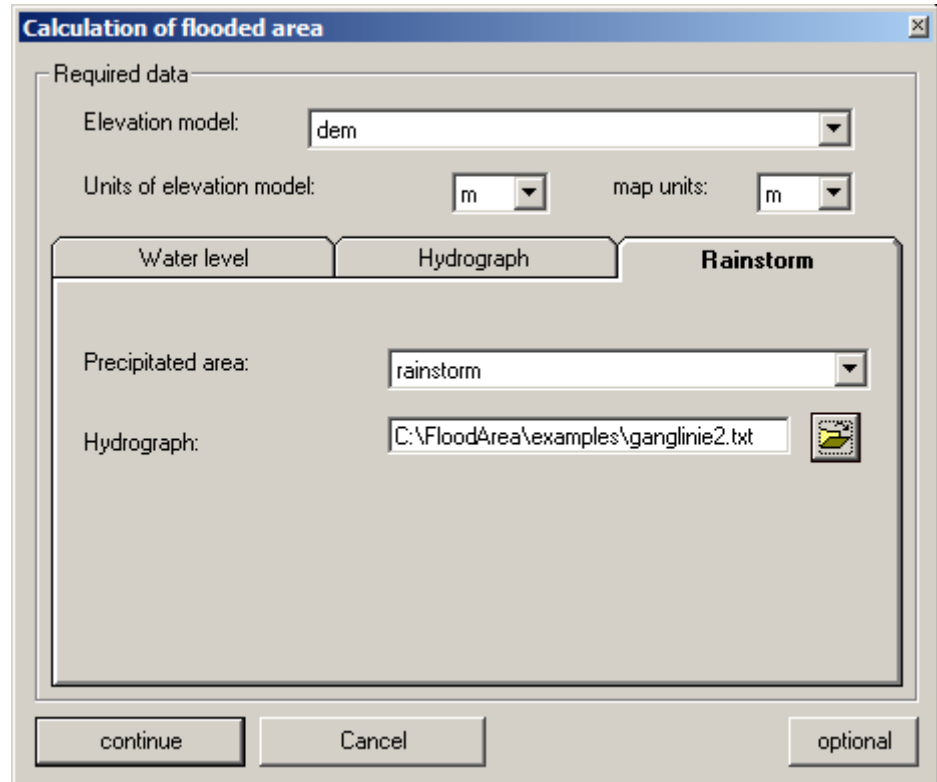
Please notice: the model stops either when the time specified in the dialog **Additional settings** has run out, or when the last record of the hydrograph data file has been processed, whatever comes first.

Rainstorm (input by area)

This option is almost identical to the one described above, the most important difference being that the hydrograph is not given for one input coordinate but

for an area. This area is defined by a grid theme. Thus, only one column in the input data file can be considered.

The format of the hydrograph data is the same as above. Values, though, must be given in units of mm/h. Output is calculated for the model edge only. An output file (*.out) is produced in the same way as described above. Values of the output file are in m³.



Calculation of flooded area

Required data

Elevation model: dem

Units of elevation model: m map units: m

Water level Hydrograph **Rainstorm**

Precipitated area: rainstorm

Hydrograph: C:\FloodArea\examples\ganglinie2.txt

continue Cancel optional

Different from the option Hydrograph, instead of coordinates for input/output locations, a grid theme representing the area for the hydrograph data must be chosen. Grid cells containing the value “zero” or “NODATA” are considered to be “dry” cells, i.e. cells without water input. All other values given will be multiplied with the value in the hydrograph data file allowing for a **weighted input**. If a weighted input is not desired, all values must be set to 1. No negative values should be given.

In general the two hydrograph options are the same. Using the areal input with a grid containing only a single cell, the results of the simulation are the same compared to using the normal hydrograph option. But before running the rainstorm option you have to consider the different input units. Pay attention to the fact that the conversion factor depends on the cell size. Here some examples:

An input of 1 m³/sec

at a cell size of:

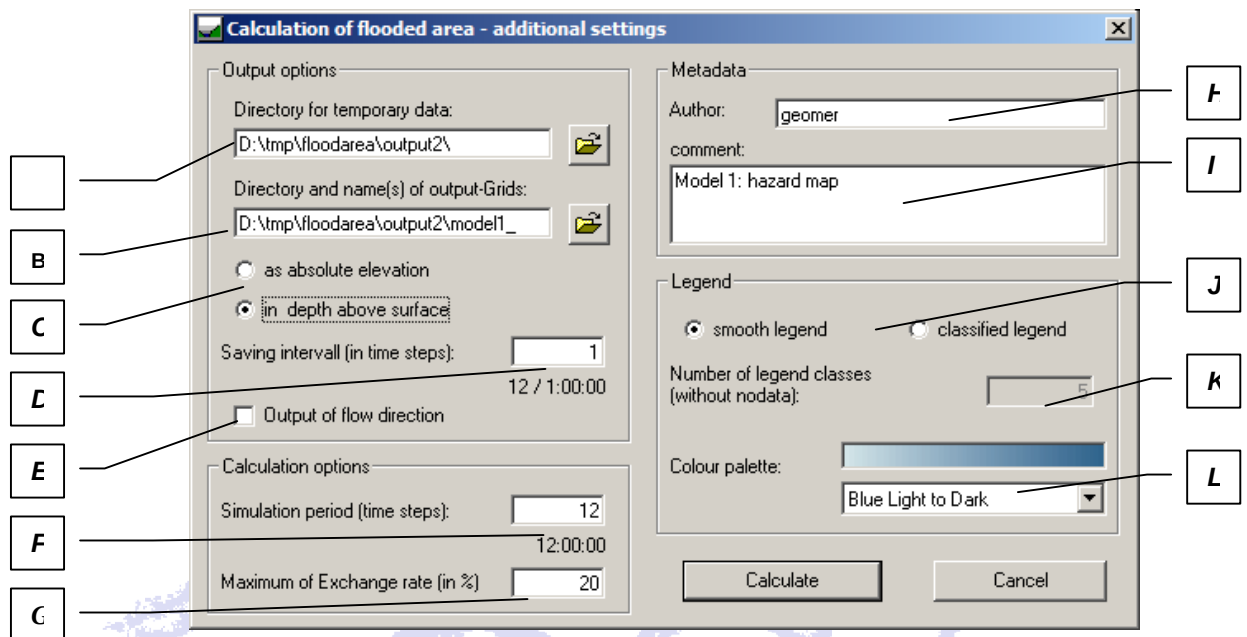
is the same than an intensity of:

5 m * 5 m	144 000 mm/h
10 m * 10 m	36 000 mm/h
20 m * 20 m	9 000 mm/h
25 m * 25 m	5 760 mm/h
30 m * 30 m	4 000 mm/h
40 m * 40 m	2 250 mm/h
50 m * 50 m	1 440 mm/h
100 m * 100 m	360 mm/h

If you want to use this function like the first you have also to divide the calculated intensity by the sum of the cell values of the weight grid. You also can make this correction by manipulation the weight grid, for example if you use 10 cells for input, apply to all of them a value of 0.1.

Additional settings

All simulation methods will be controlled by additional settings. The dialog for these will be activated after clicking the *continue* button.



Output options

Use this dialog to specify a directory (**field A**) for the temporary GRIDS produced during the model run. Also use this dialog to specify a name for the output GRIDS in **field B**. The name will be completed automatically by a sequence number, i.e. the first grid will be named *floodarea1*, the second *floodarea2* etc.. Please be aware that already existing GRIDS with identical names will be overwritten without further warning.

In the **option field C**, the model output values can be given in absolute elevation (in most cases this means above sea level) or it may indicate water depth above the surface. In any case the units will be the same as the units chosen for the elevation model. The interval of the time steps (i.e. the interval for which intermediate GRIDs will be saved) can be chosen in **field D**. One time unit accounts for approximately one hour of time. This value is only an estimate because the model is not calibrated.

The **check box E Output of flow direction** needs to be activated if you want to generate a shape file with the flow direction later on. Please note that this will generate three grids instead of one for each output time step, so provide enough disk space if you intend to use this option.

Calculation options

Simulation period (field F) is the total simulation time (approx.) in hours. If the model run is a continuation of a previous simulation, the simulation time will be extended by the given value.

The maximum exchange rate (**field G**) defines the percentage of water volume present in the current grid cell, which is distributable to the neighboring cells. In order to meet this condition, the model decreases the internal iteration time step. Thus, the value has influence on the simulation speed. If values are high, a wave instability can be the result, which will not stop the model but may produce undesirable results. Values between 10 and 30 % have proven to be good choices.

Metadata

In order to save information about the GRIDs produced by model runs, FloodArea makes use of the metadata concept of ArcGIS. Some of the metadata will be saved automatically (e.g. the simulation period), other information can be specified by the user. There is the possibility to give an author name in **field H** and a comment in **field I**.

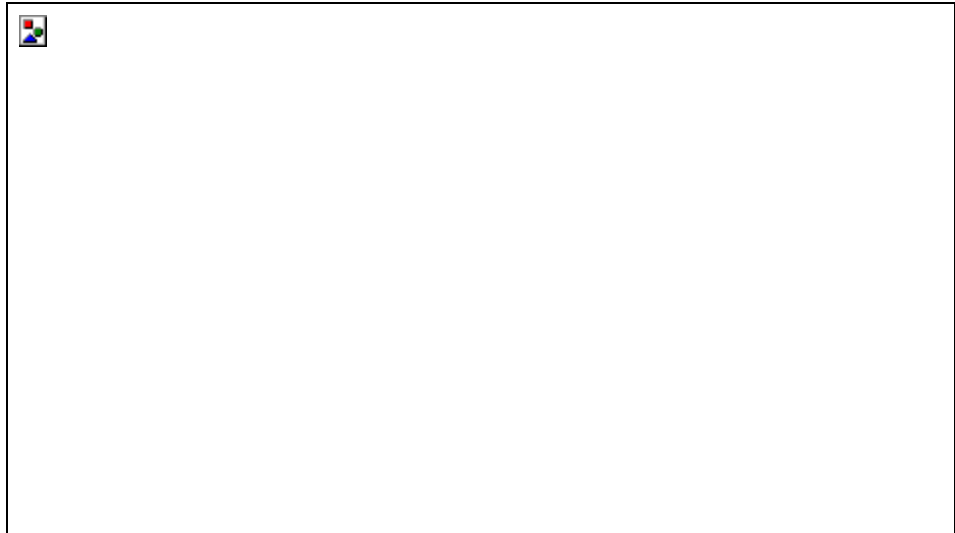
Metadata will be explained in detail later in this manual.

Legend

In this section ArcMap specific legend options for the output raster layers can be specified. NODATA values are set transparent by default. Choose between a classified or continuous smooth legend in *option J*, and select a color ramp in **J**. If a classified legend is chosen, the number of classes can be given in **field K**.

Display simulation info / Continue simulation

With this dialog you can display information about previous model runs or continue a previous simulation run. The latter option is only available, if model input was done using a drainage network grid.



The information is shown either for a grid layer present in the active view or for a grid stored on disk.

In the *input section* the specifications made for producing the GRIDs will be displayed. In the *output section* specifications made in the additional setting (see above) are shown.

Some notes for explanation.

true means that a specific option was set.

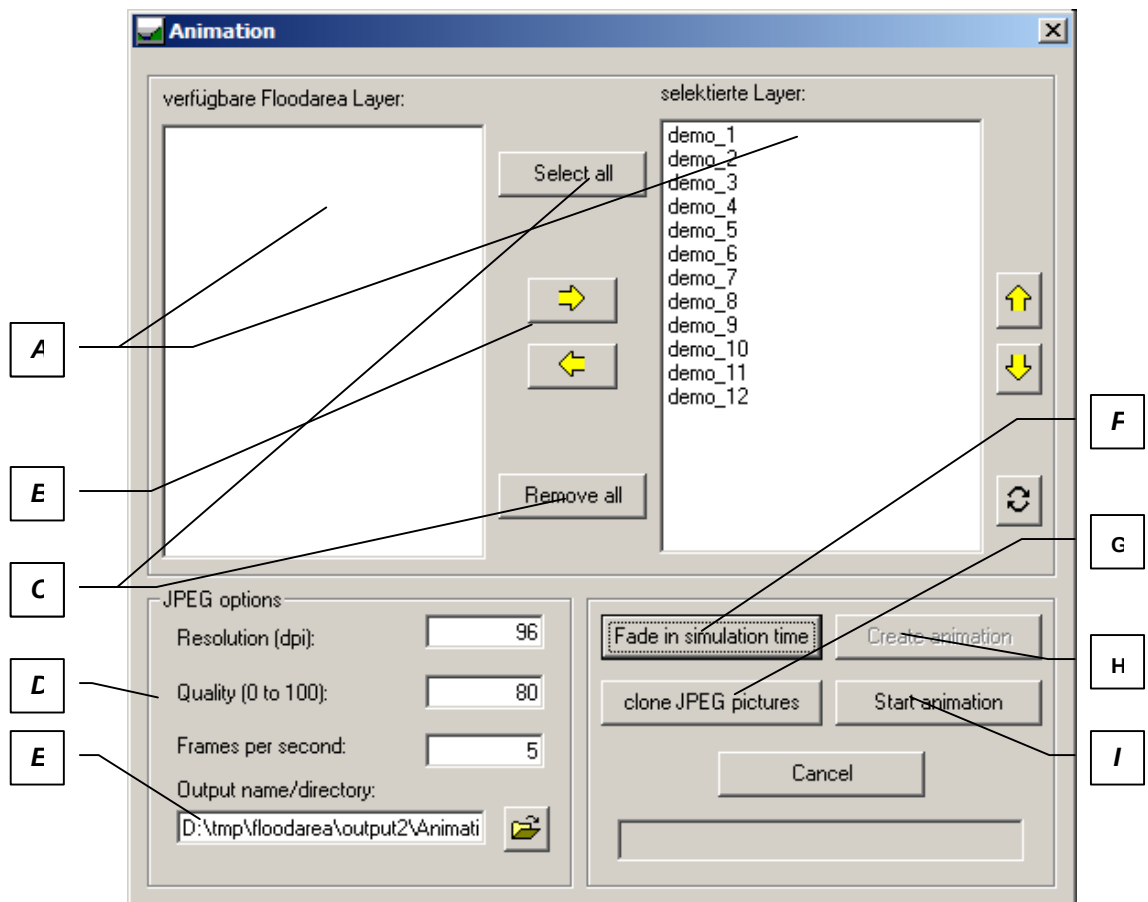
In case of a continued simulation the specified simulation duration (see *additional settings*) is added to the already passed simulation time for that particular grid.

If a calculation is continued the program itself is searching for the correct time step in the hydrograph files.

The simulation parameters can be changed to continue a simulation with different settings.

Create / display animation

Using this option a better visualization of model simulations can be achieved than using ArcMap. A series of JPG images and an additional animation in AVI format can be produced with FloodArea.



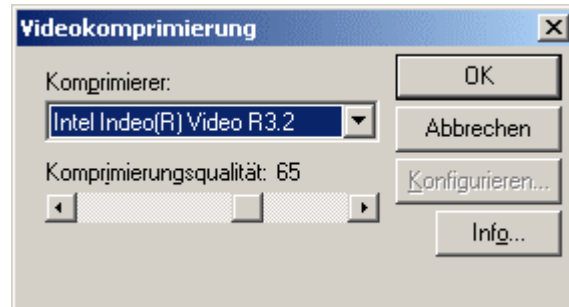
Raster layers to be included in an animation are managed in **List A**. Here, layers can be moved (**buttons B**), added or deleted (**buttons C**). Specify JPG quality and resolution, and AVI speed in **fields D**. The list will only contain FloodArea layers. Other layers in the data frame will be displayed according to their visibility status automatically. Thus, if you want a particular background, switch off or on the layers you need.

In **field E** the output directory for the images and movies can be defined.

With **button F**, the option to include the simulation time of each individual raster layer in the image or movie is given. The time will taken from the metadata associated with each grid. If a movie is produced, this option will cerate the effect of a clock.

Pressing **button G** will start the creation of JPG images without producing an avi movie.

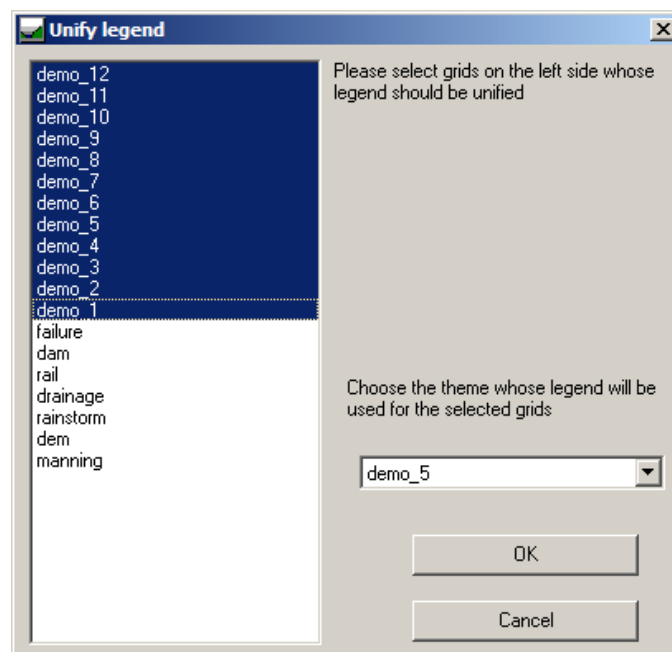
Pressing **button H** must be clicked for starting the creation of an animated movie. It can only be activated if the jpg images already exist. Various compression options can be chosen in the following dialog (in german only).



Existing animations can be started by clicking on **button I**.

Unify legend

Use this option to assign an identical symbology legend to selected grids.

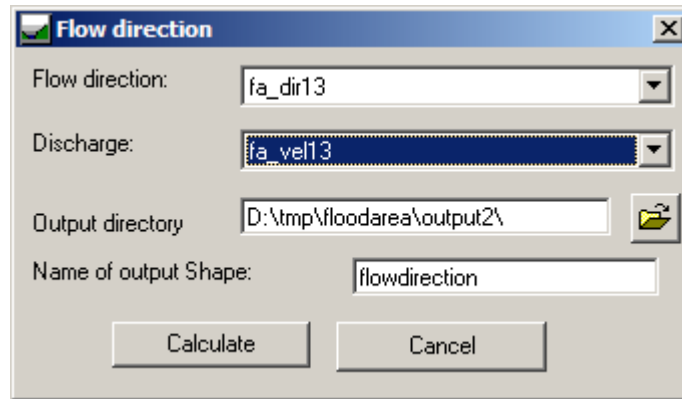


First, in the left list select the FloodArea layers which should have the same legend, then select in the right selection box the raster layer with the desired symbology to be used as a template for all others.

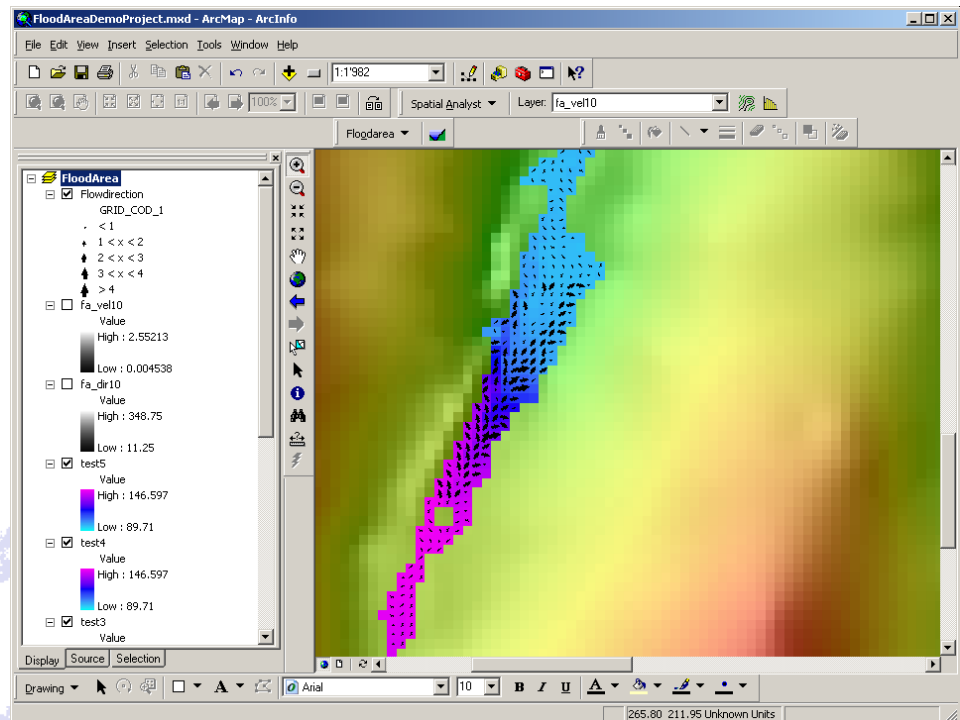
Create shape of flow direction

By using this menu option one can generate a shape showing the direction of flow. To create such a shape you have to select two grids, one representing flow direction, and one representing discharge or velocity. These grids can be produced during the model run by checking this option in the *additional settings*. The grids can be loaded from disk if they are not already loaded in the current data frame.

- ☐ fa_vel13
- ☐ fa_dir13
- ☒ demo_13
- ☐ demo_12
- ☐ demo_11



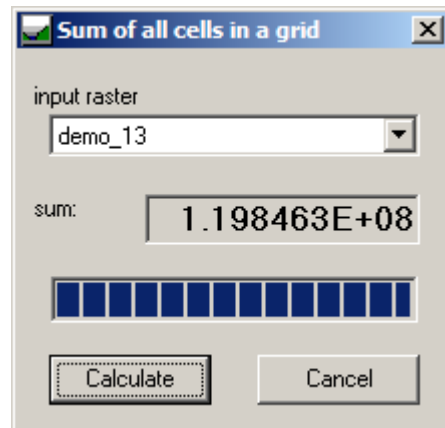
If the arrows showing the direction are displayed too large or small, this may be caused by the missing or wrong unit input within the Layer properties. Please refer to your ArcMap manual. The arrows are set to scale 1:1000 to fit to the demo data.



For presenting the flow direction 16 directions can be shown, according to the internal relation of raster cells in FloodArea. This will produce a uniform flow direction picture. It must be considered that flow directions are snapshots of a dynamic process. Particularly in terrain with rapidly changing flow direction it is best to output several situations.

Summarise grid values

All values of the active grid theme are being summed up using this function. Given the case that for instance the flooding depth is given and horizontal and vertical units are identical, the present total volume of water is put out. Thus, reliable volume balancing can be realized.



Choose language

FloodArea offers the possibility to choose the language used for the dialogs, the help texts and the messages displayed during the model run. Currently available are German, English and Spanish, the default is German. Use **OK** to switch to the chosen language. You do not have to restart the program or reload the extension.



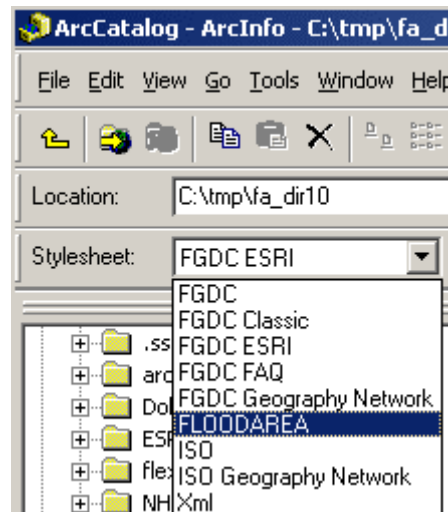
Info

Use the **Info** button to display the version number, license number and service addresses.

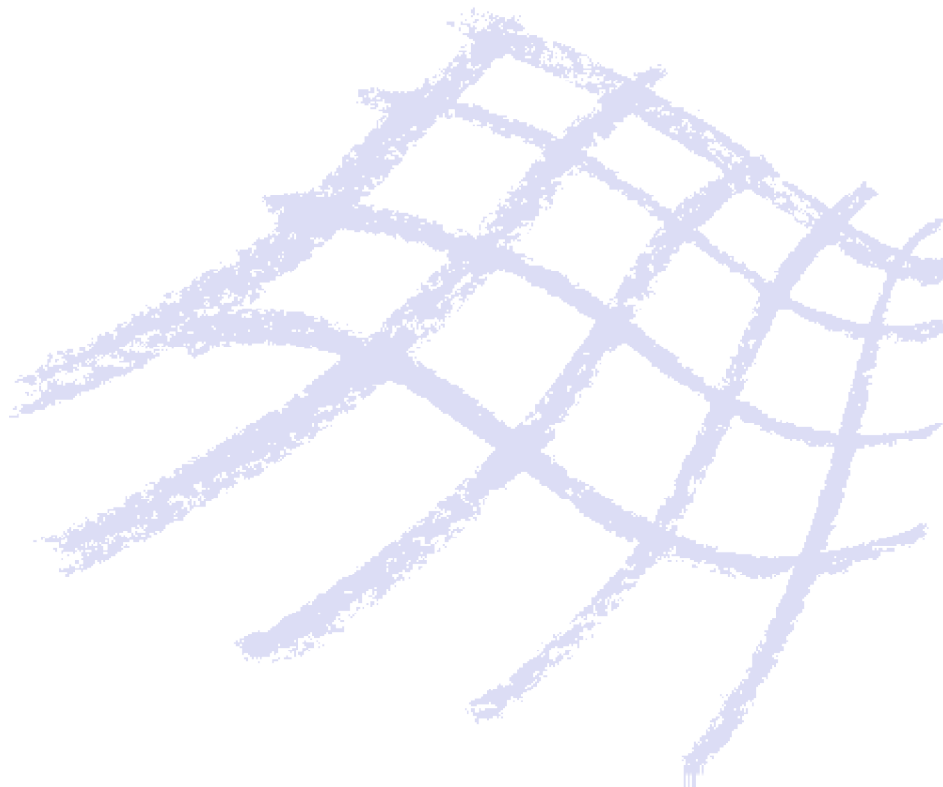


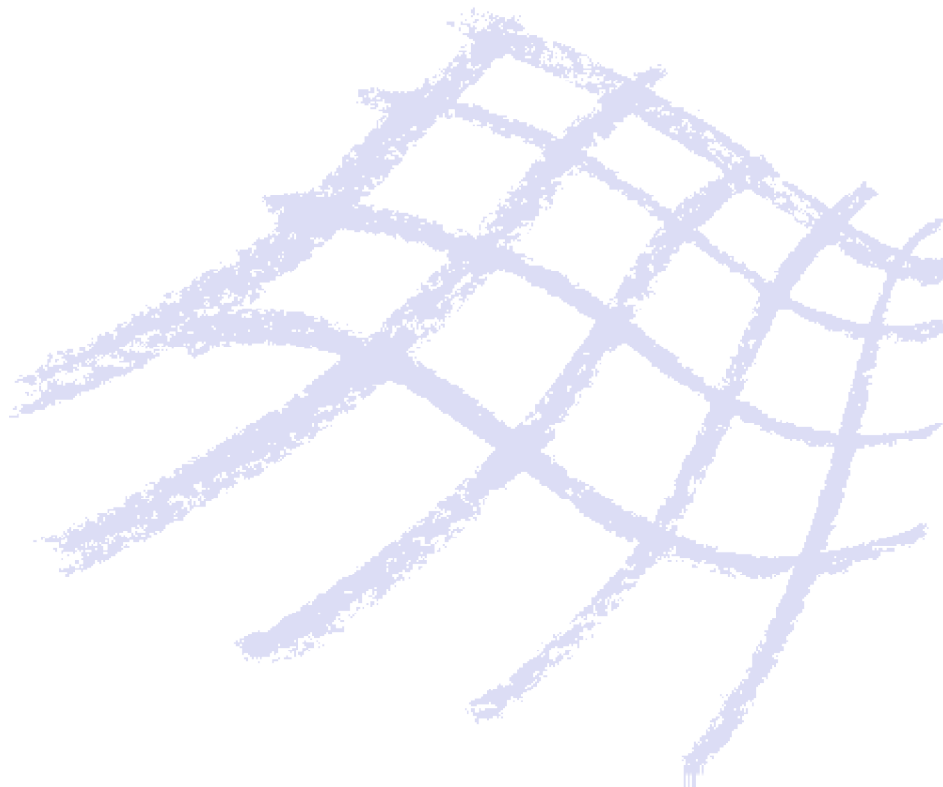
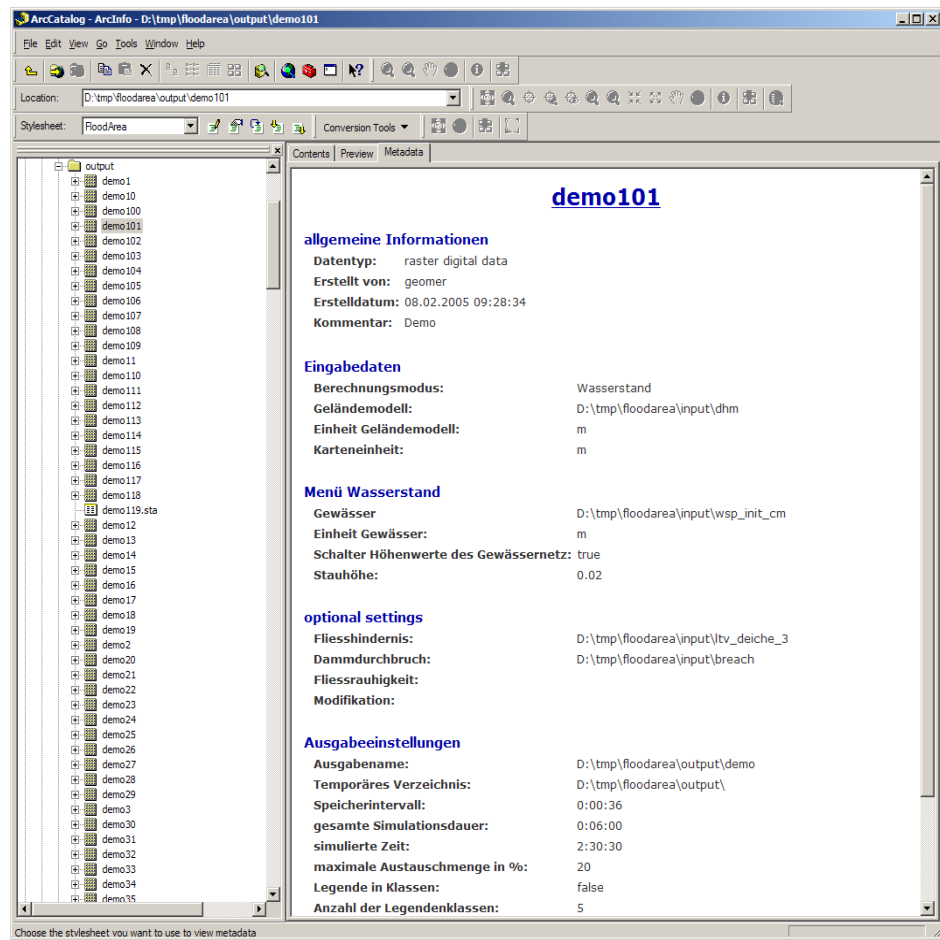
Metadata managment

FloodArea makes use of the metadata concept of ArcGIS for storing information about utilized input data and produced model results. The XML definitions of the ISO standard have been extended with specific FloodArea elements. In order to view the metadata produced by FloodArea just select the FloodArea stylesheet in ArcCatalog.



Additional Metadata produced or edited with standard ArcCatalog tools can still be added, without losing any of the Metadata produced by FloodArea.





Calculation Method

The calculation of inundation areas is based upon a hydrodynamic approach. All eight neighbors of a raster cell are considered. The discharge volume to the neighboring cells is calculated using the Manning-Strickler formula.

$$V = k_{St} \cdot r_{hy}^{2/3} \cdot I^{1/2}, \text{ with } r_{hy} \text{ being the hydraulic radius and } I \text{ the gradient.}$$

For looking up appropriate values of k_{St} (roughness) reference tables can be used, which renders the use of this formula more practicable compared to others. The quality of simulation results depends very much on using appropriate roughness values since flow velocity is linearly related to roughness.

The flow depth during an iteration interval is taken from the difference between water level and maximum terrain elevation along the flow path.

$$flow\_depth = water\_level_a - \max(elevation_a, elevation_b)$$

The inclination and the direction of the water table is re-calculated in every iteration step and the steepest slope used as the inclination in the Manning-Strickler formula.

$$slope = \sqrt{\left(\frac{\partial z}{\partial x}\right)^2 + \left(\frac{\partial z}{\partial y}\right)^2}$$

$$aspect = 270 - \frac{360}{2\pi} \cdot a \tan 2 \left[\frac{\partial z}{\partial y}, \frac{\partial z}{\partial x} \right]$$

In cases of linear elements with a width of just one raster cell, this method will fail, because the steepest slope may be perpendicular to the actual direction of flow. This is the case when the inclination of the river bed (e.g. in a small ditch) is lower than the surrounding topography. To avoid such errors, slope calculations are internally tested for their plausibility by comparing the elevation of the central raster cell to the elevation cell of the slope direction (aspect). If the difference is exceeding a certain threshold, inclination is re-calculated by comparing it with the lowest neighboring cell.

For illustration purposes examine the simplified elevation model shown below, depicting a ditch, which has an inclination lower than the surrounding terrain.

79.0	79.0	79.0	79.0	79.0	79.0
78.0	78.0	78.0	78.0	78.0	78.0
72.9	73.0	73.1	73.2	73.3	73.4
75.0	75.0	75.0	75.0	75.0	75.0
74.0	74.0	74.0	74.0	74.0	74.0

Slope direction derived by standard GIS Spatial Analyst. In the line of the ditch, slope values are wrong:

↓	↓	↓	↓	↓	↓
↓	↓	↓	↓	↓	↓
↓	↓	↓	↓	↓	↓
↑	↑	↑	↑	↑	↑
↓	↓	↓	↓	↓	↓

Slope direction values in the ditch, as derived by FloodArea:

↓	↓	↓	↓	↓	↓
↓	↓	↓	↓	↓	↓
←	←	←	←	←	←
↑	↑	↑	↑	↑	↑
↓	↓	↓	↓	↓	↓

Flow velocity as derived by the formula is multiplied by the flow cross section and the iteration time step in order to get the exchanged water volume between cells for the current iteration.

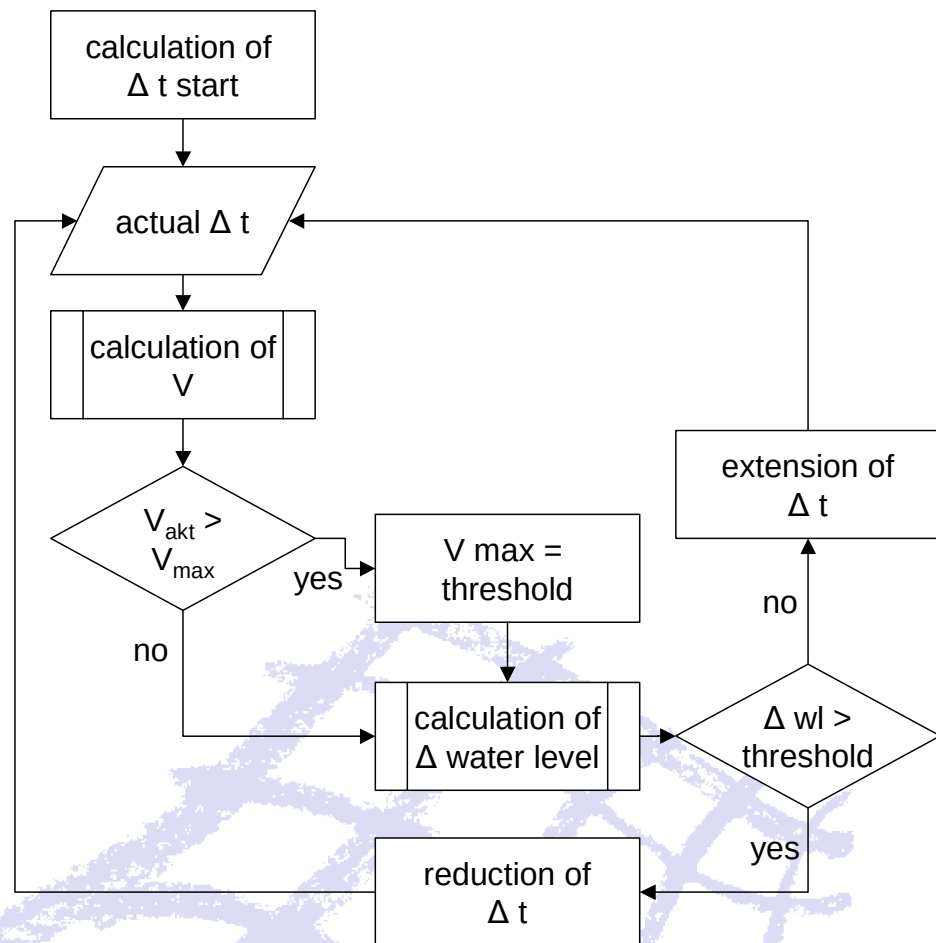
The Manning-Strickler formula is usually valid only for normal discharge, where loss due to friction equals the gain in potential energy. In other cases calculated velocities values may be too high. To control this, the velocity values are checked for the threshold criterion:

$$\text{threshold\_criterion } V = \sqrt{g \cdot h}$$

Together with the volume also the velocity vectors are passed for the next iteration. Mean flow velocity is defined as the arithmetic mean of the current

velocity calculation and the vector addition. By this, sudden changes in flow behavior will be minimized and inertia effects rendered in a simplified way.

The smallest iteration time step is adjusted dynamically. An important control criterion for this adjustment is the amount of water available. If the discharge rates become too large compared with the available volume, the iteration time step will be reduced. Only water level changes exceeding 1mm are considered by that control mechanism. If the volumes exchanged between cells are very small, the algorithm will increase the iteration time step. This permanent optimization keeps processing time at a minimum.



Volume Budget

At the end of each iteration the computed discharge volumes are shifted between cells, thus no volume can be lost.

To feed water to the model the three options

- drainage network or
- hydrograph
- rain storm

are available.

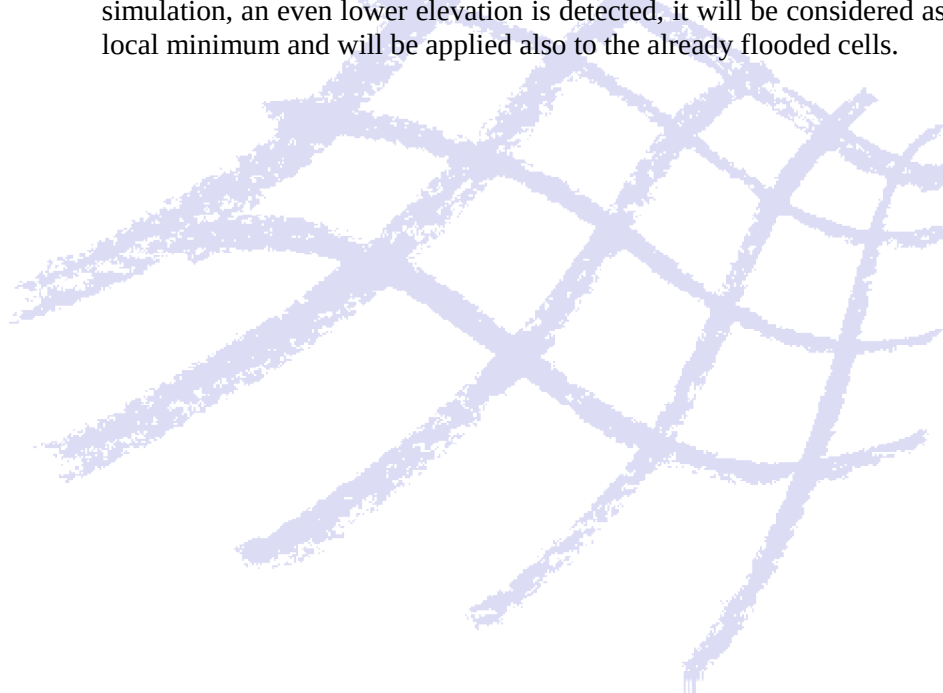
Using the first option, the algorithm sets all cells of the initializing network back to their original values after each iteration.

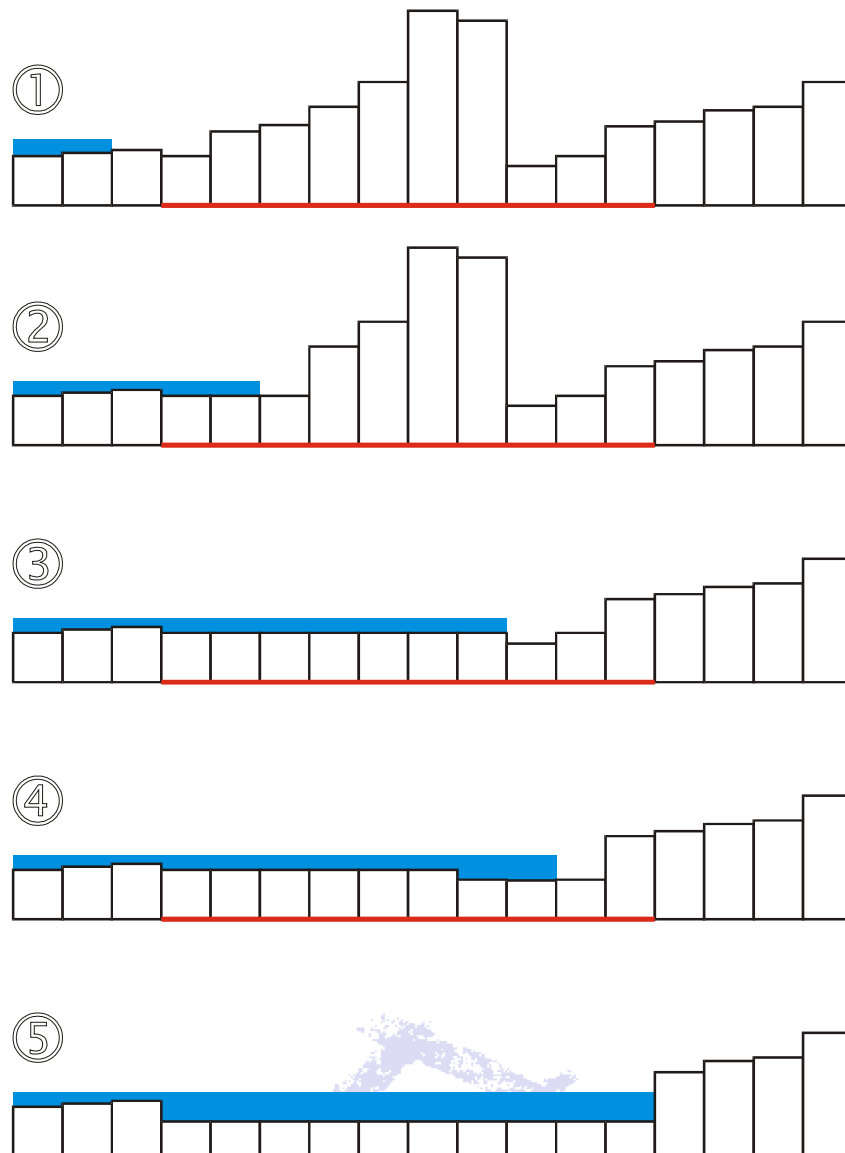
Using the second option the amount of water fed to the model is defined by the hydrograph. The amount of water taken out from the model is specified by selecting an output location.

Using the rain storm option „pours“ water over the terrain with a temporal distribution defined by a file. Spatially the distribution is defined by a GRID representing the portion at each cell location. A value of 1 is equal to 100%.

Dam Failure

In terms of a dam failure grid not only potential physical obstacles must be „broken“, but also appropriate flow depth values must be calculated. The assumption is, that the lowest elevation in the area covered by the dam failure grid (red area) is the local elevation minimum. If water reaches that area, the elevation at that location will be reduced to that local minimum. If, during the simulation, an even lower elevation is detected, it will be considered as the new local minimum and will be applied also to the already flooded cells.



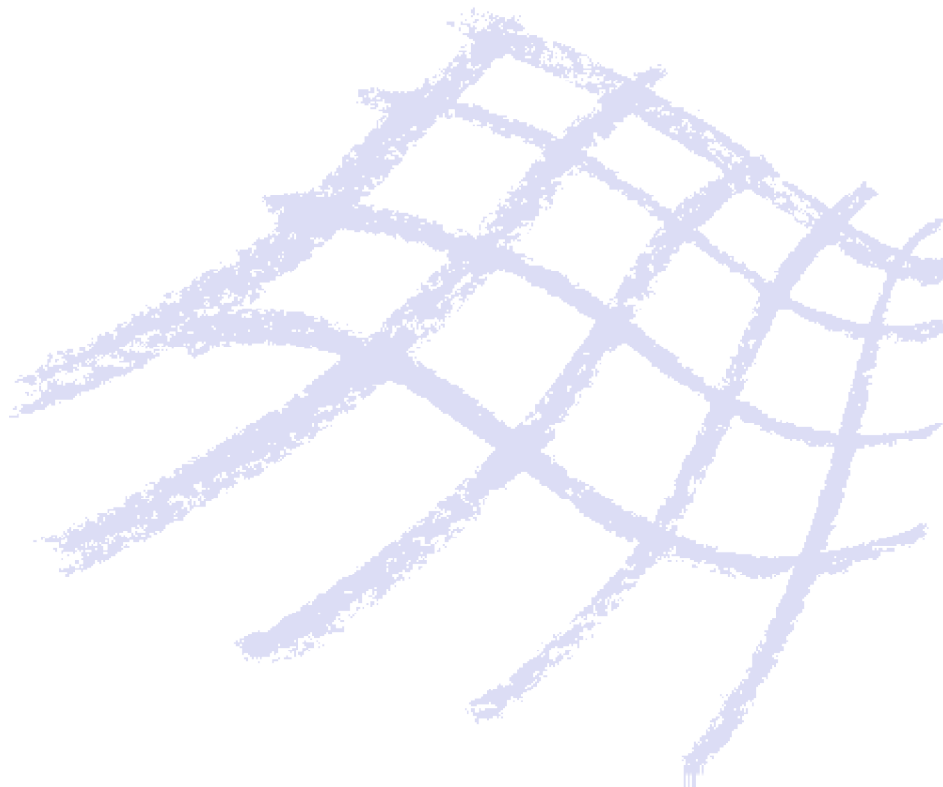


The figures show, in a schematic way, characteristic intermediate phases during a dam failure simulation. From figure 2 onwards, a reduction of the elevation values takes place, being one cell “ahead” of the water level (shown as a horizontal plane for simplification). From figure 4 onwards, the new, even lower minimum is applied also to the cells processed before. Figure 5 shows the final status.

Consideration of Model Edges

Considering the edges of a model area may cause a problem because no information is available for the area beyond the study area. **FloodArea** assumes a continuing gradient of the water surface beyond the edge of the model. Based upon this assumption, the water is being taken out of the model according to the discharge volumes calculated. A piling up at the model edges is not possible. If the model run is controlled by a hydrograph data file, the water volume taken out at the model edges is written to a separate file named “*.out”, “*” being the name of the hydrograph data file. The volume is specified in m³ since the last

iteration time step. If a high temporal resolution is desired, this needs to be accounted for in the hydrograph data file. No “*.out” file is created for the option “water level”. Since no defined water volume is fed into the model, an output hydrograph would be meaningless.



Examples

Delineation of Flooded Areas Based Upon Flood Marks

Quite often historical floods are only registered at individual locations but not to their overall extent. The levels taken from these locations can be used to run **FloodArea**. The simulation model uses these points (or lines) as initialising cells to flood the surrounding terrain. Elevation differences are interpolated appropriately in terms of the hydraulic model.

Dam Failure Scenarios

Two possible scenarios can be modeled. The first describes a complete failure of a dam or a section of a dam. Using the option Water level (*elevation of drainage network*) it is assumed, that the dam failure will not influence the water level of the main stream. The second possibility describes a scenario with a defined inflow into the protected area (one or more cells) using a hydrograph.

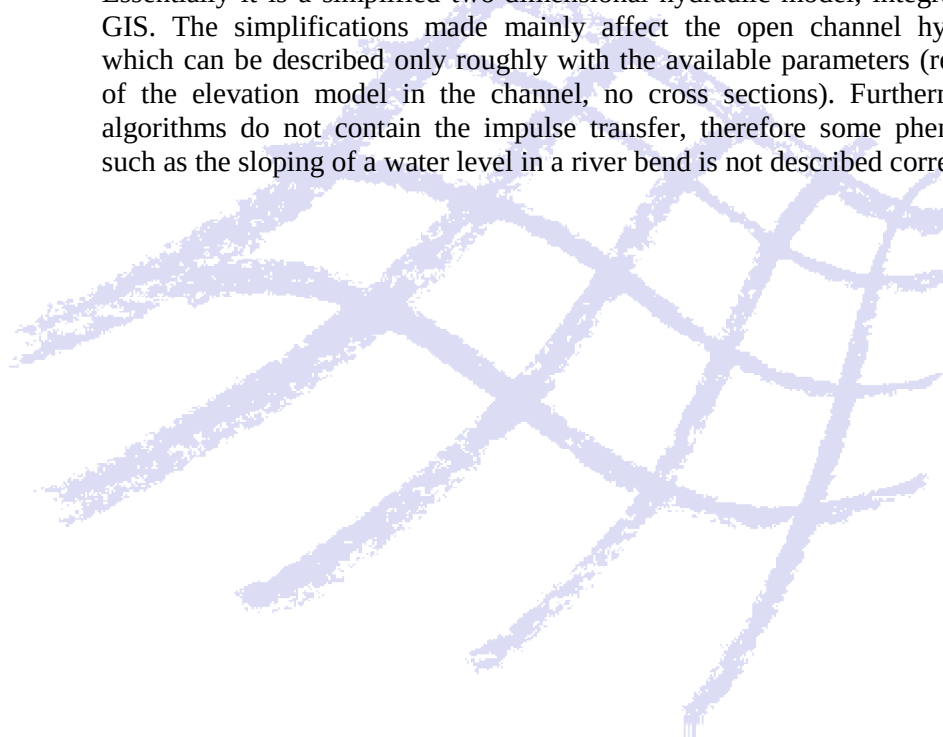
Only in the first case it is assumed that water continues to flow behind the dam.

Controlled Outlet of Flood Control Basins

Given the case that controlled outlet of a flood control basin is necessary, a flooding of other areas might occur. These areas can be delineated by using the design hydrograph data for that particular location.

Limitations

FloodArea is primarily intended to calculate areas affected by a flood. Essentially it is a simplified two-dimensional hydraulic model, integrated in a GIS. The simplifications made mainly affect the open channel hydraulics, which can be described only roughly with the available parameters (resolution of the elevation model in the channel, no cross sections). Furthermore the algorithms do not contain the impulse transfer, therefore some phenomenon such as the sloping of a water level in a river bend is not described correctly.

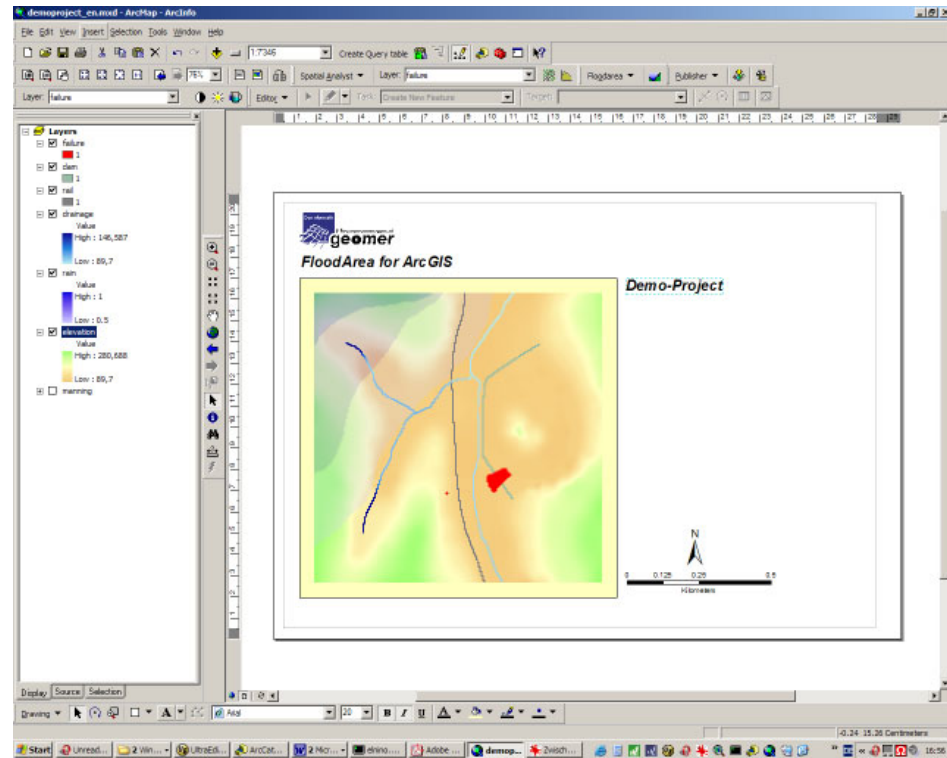


Demo Version and Demo Data

Notice

The demo version is functional only when using the demo data that comes with it. The demo data comprises of:

Demo project



elevation: an elevation model (units are meters) with a horizontal resolution of 5 m, 200 rows and 200 columns, corresponding to an area of 1 km²,

drainage: a grid representing a drainage network, values represent water levels and are given in meters,

rail: a grid representing flow barriers with interruptions, for example bridges in a railway dam,

dam: an uninterrupted flow barrier,

failure: a grid representing a failure area (adapted to the dam grid),

manning: a grid representing roughness coefficients (values are in 1/n); landuse classifications upon which these values are based can be found in the legend (manning.avl),

rain: a grid representing weight factors for the option Rainstorm (Areal Input), see page 16,

Two hydrographs representing an artificial (hydrograph1.txt) and a natural hydrograph (hydrograph2.txt).

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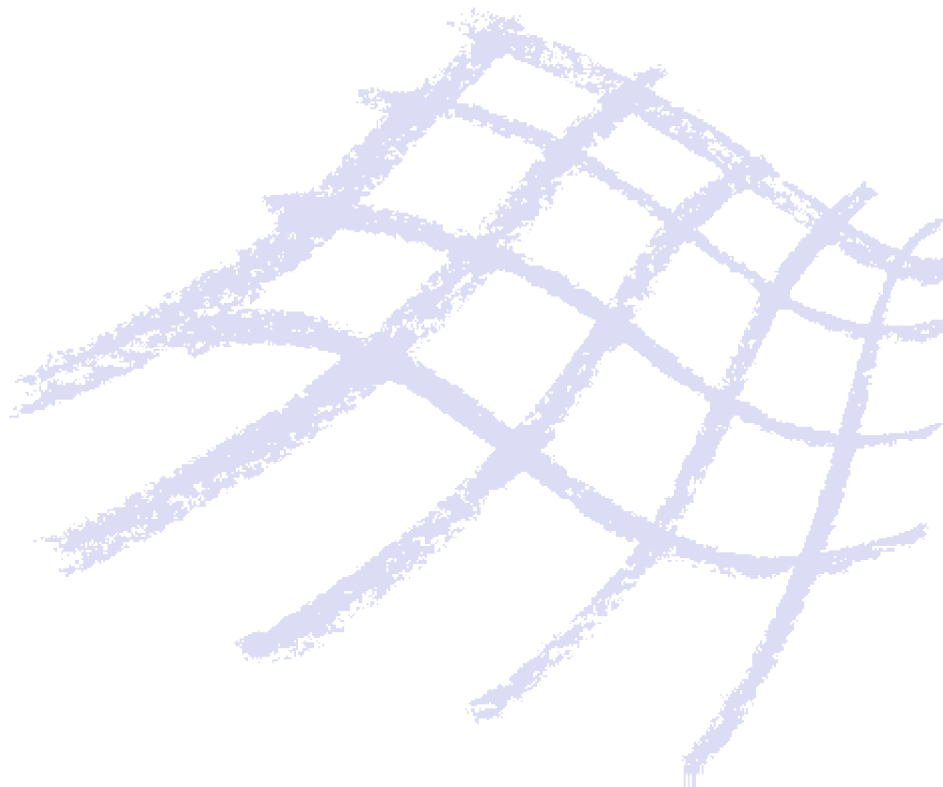
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